Stephen Cauffman

From: wtc@nist.gov
Sent: Tuesday, September 09, 2008 2:55 PM
To: Stephen Cauffman
Subject: Fwd: Submittal of Comments - NIST WTC7 report
Attachments: Submittal of Comments.doc

>X-Sieve: CMU Sieve 2.3
>X-ME-UUID: 20080903074132172.0430B7000092@mwinf2e24.orange.fr
>From: Anders Björkman <anders.bjorkman@wanadoo.fr>
>To: <wtc@nist.gov>
>Subject: Submittal of Comments - NIST WTC7 report
>Date: Wed, 3 Sep 2008 09:41:15 +0200
>X-Mailer: Microsoft Outlook Express 6.00.2900.3138
>X-Proofpoint-Virus-Version: vendor=fsecure
>engine=1.12.7160:2.4.4,1.2.40,4.0.166
>definitions=2008-09-03_05:2008-09-02,2008-09-03,2008-09-03 signatures=0
>X-PP-SpamDetails: rule=spampolicy1_notspam
>policy=spampolicy1 score=0 spamscore=0 ipscore=0 phishscore=0
>bulkscore=0 adultscore=0 classifier=spam adjust=0 reason=mlx
>engine=5.0.0-0805090000 definitions=main-0809030004
>X-PP-SpamScore: 0
>X-NIST-MailScanner: Found to be clean
>X-NIST-MailScanner-From: anders.bjorkman@wanadoo.fr
>X-NIST-MailScanner-Information:
>
>Dear Madame/Sir,
>
>pls find attached and below comments re subject.
>Hopefully you find the comments of interest that will enable you to
>improve the draft report.
>Please acknowledge receipt and I.D. number and
>person(s) handling the comments, if that is part of your procedures.
>
>Kind regards
>
>Anders Björkman
>
>
>Submittal of Comments - NIST WTC7 report
>
>
>
>Name: Anders Björkman, 6 rue Victor Hugo, F 06240 France
>Affiliation: President, Heiwa Co, European Agency for Safety at Sea
>(address as above)
>Contact: +336 61725424, anders.bjorkman@wanadoo.fr
>
>Reference number: 2008/9/001
>
>Date: 9/3/2008
>
>
>
>Report Number: NIST NCSTAR 1-9 Volume 2 Page Number: 455-536

>Paragraph/Sentence: Chapter 11 - 11.2 ANSYS Model, 11.3 Analysis
>results
>
>
>
>Comment No. 1: In structural damage analysis - as opposite to
>structural design analysis - it is not load paths of the intact
>structure that is of interest, but the path of failures from the first
>small local failure due to a known cause (e.g. fire/heat/thermal
>expansion) to the end of destruction including all structural failures
>in between as a consequence of the first, small failure. Such a damage
>analysis shall identify the critical failure in the path, i.e. could
>that critical failure be avoided; the destruction would have been
>arrested there. Most local failures in steel structures luckily do not
>progress to create a critical failure that causes the complete
>structure to globally collapse. The destruction is generally arrested
>long before that.
>
>
>
>The NIST WTC7 draft report unfortunately fails to do this proper
>structural damage analysis:
>
>
>
>It is not clear in what order the various local structural failures
>take place in the ANSYS model, what elements/nodes are affected,
>details of failure, cause of failure and consequence of failure
>(serious or can it be ignored?) and how the boundary conditions (loads
>on columns at floor 16) are affected.
>
>
>
>Reason for Comment: The ANSYS model, only 16 floors high in lieu of 47,
>consists of primary (vertical steel columns connected to ground),
>secondary (horizontal and sloping steel beams connected to primary
>parts) and tertiary parts (e.g. floor elements and walls connected to
>secondary parts; beams) and associated connections, and it is of vital
>importance to know the order or path of failures. We know that the
>structure at ambient temperature is very low stressed and thus looks
>very safe. Purpose of the exercise is to find the critical, proximate
>failure that caused the collapse.
>
>
>
>Fire/heat/thermal expansion may affect a tertiary member that heats up
>quicker than adjacent secondary members and the local connections may
>fail and the tertiary part is out of action but it hardly affects the
>effectiveness of the secondary parts, which of course is verified when
>the FEA analysis is re-done after each failure. The secondary parts and
>their connections (bolted or welded) to primary parts are much stronger
>than those of tertiary parts and will deflect and deform with the
>primary parts and it is highly unlikely that thermal expansion will
>produce forces that break the much stronger connections between
>secondary and primary parts. It is noted that a critical failure mode
>may be buckling of one primary structure column losing supports by
>secondary structure floor beams.
>

>
>
>Suggestions for Revision: Chapter 11.2 to be expanded with a list of
>all local failures in order of occurrence with details and seriousness
>as outlined above in Comment No. 1. After each failure the condition of
>the model is evidently re-analysed by FEA and the results of each
>element (primary, secondary and tertiary) summarized in Chapter 11.2.
>Doing that we will know when the situation becomes really serious, e.g.
>when/if a primary part starts to get affected. Evidently a global
>collapse is only possible if primary structural parts are affected and
>we are interested in all local failures leading to that critical
>failure; the proximate cause of collapse. The draft report Chapter 11
>is incomplete in this respect.
>
>Example how to improve the report:
>
>1. Tertiary structural elements connected to a floor beam fail due
>heat/thermal expansion.
>These failures/causes are easy to list.
>
>2. Secondary structural elements (beams with or w/o floor elements)
>connected to a column fail.
>These failures and their causes should also be easy to list, but here
>the explanations must be more complete. If, e.g. a beam connection to
>the column becomes disconnected, we must know exactly how and why
>(because you do not expect that to happen).
>
>3. Primary structural elements (e.g. column 79) fail. If cause of
>failure is buckling due to loss of supports of secondary floor beams
>(and not thermal expansion), say so, but explain how many secondary
>structural beams must fail before the critical failure of the primary
>column becomes imminent. This failure to a column evidently affects the
>boundary conditions, so you have to move on the next model to find out
>what really happens outside the model.
>
>Unfortunately you do not know if this failure of a column in the ANSYS
>model is the critical one, as you do not know what happens above floor
>16.
>Evidently a failed column cannot carry any load, so either the load
>carried drops off or is transmitted to other elements, but in either
>case the boundary conditions changes; the loads applied at floor 16 change!
>
>It would be very easy to extend the ANSYS model to 47 floors to solve
>that uncertainty. Then you can see how each failure below floor 16
>affects the load distribution above floor 16. Thus it is suggested that
>the ANSYS model is also extended to floor 47 in your final
>analysis/report.
>
>
>
>
>
>Report Number: NIST NCSTAR 1-9 Volume 2 Page Number: 537-600
>Paragraph/Sentence: Chapter 12
>
>
>Comment No. 2: The LS-DYNA 47 floors model is very big with >3 million
>elements and >3.5 million nodes and the data of a partly damaged ANSYS

>model incl. boundary conditions is copy/pasted into it to represent the
>starting
>(stable?) condition with local damages below floor 16. As shown in
>Comment No. 1 the details of the damaged ANSYS model are not clear and
>it is not certain, if it represents a realistic starting condition.
>Another question is if you can copy/paste data of a locally damaged
>structure into an undamaged one? What about the boundary conditions at
>floor 16? Another question is the reliability of the LS-DYNA software.
>Has it been tested properly? It does not seem to be commercially
>available.
>
>
>Reason for Comment: The LS-DYNA, like the ANSYS model, consists of
>primary (vertical columns connected to ground), secondary (horizontal
>and sloping beams connected to primary parts) and tertiary parts (e.g.
>floor and wall elements connected to secondary parts; beams) and
>associated connections, and it is again of vital importance to know the
>order or path of failures. We know that the structure at ambient
>temperature is very low stressed and thus looks very safe.
>
>
>
>Heat/thermal expansion may at this time have affected tertiary parts
>below floor 16, the local connections of which may have failed and the
>tertiary part is out of action and it has apparently affected the
>effectiveness of the secondary parts, but the situation is not clear
>(as Chapter 11 is incomplete). The secondary parts and their
>connections to primary parts are much stronger than tertiary parts and
>will deform and deflect with the primary parts and it is highly
>unlikely that thermal expansion will produce forces that break the
>connections between secondary and primary parts. However, it is assumed
>here that some secondary and primary parts below floor 16 have actually
>failed (causes to be established) and shifted a column (No 79?) out of
>initial locations affecting the boundary conditions at floor 16, but
>that the structure below floor 16 is still stable.
>
>
>
>It is of vital interest to know how these local failures below floor 16
>immediately affect the virtually undamaged structure above, when (A)
>the analysis starts (how serious are the failures below?) and (B) every
>further failure that follows below and above floor 16 and finally, (C)
>at the end, when all parts are rubble.
>
>
>
>It is evidently possible that when a primary column fails below floor
>16, the load on it is transmitted to adjacent columns via intact
>structure above floor 16, i.e. the boundary conditions must be modified
>in the ANSYS model analysis. Was it done?
>
>
>
>It is not clear how and why the software LS-DYNA can keep track of
>parts that are completely disconnected from the structure due to
>multiple failures.
>
>

>Suggestion for Revision: The method to
>copy/paste details of the ANSYS (Chapter 11) model at end of assumed
>failures below floor 16 produces uncertainties.
>
>
>
>It would be better to start afresh with the LS-DYNA model as completely
>free of failures and then input all the local - serious (?) failures
>- one by one - as identified in the ANSYS model below floor 16 and
>listed in Chapter 11.3 and see what happens everywhere at every
>initial, local failure and then proceed with the further failures, one
>by one, away from the first local non-critical failures, until the
>critical failure and its cause are identified.
>
>
>
>Chapter 12 thus to be expanded with a list of all further local
>failures above and below floor
>16 in order of occurrence with details and seriousness as outlined
>above in Comment No. 1.
>After each failure the condition of the model is evidently re-analysed
>by FEA and the results of each element (primary, secondary and
>tertiary) summarized in Chapter 12.4.
>
>
>
>Doing that we will know when the situation becomes really serious, e.g.
>when/if other primary parts (than column no. 79) start to get affected
>and why and what the real, proximate failure of total collapse is - the
>critical failure - and when it occurs in the failure path. Looking at
>the ANSYS model data only, it seems that column 79 could collapse
>completely due to a known cause (buckling), but that it would be the
>end of the local (serious) destruction. The other columns should not be
>affected!
>
>
>
>But apparently the failure of column 79 causes further failures of
>other primary parts and it needs to be explained - the failure path is
>to be extended. So Chapter 12 must be expanded with details of further
>failures leading to the final, critical one - the proximate failure
>initiating the global collapse. Would that proximate failure have been
>avoided for any reason, the destruction would have stopped then and
>there.
>
>Example:
>
>4. It is found that primary structural element column no. 79 fails due
>to buckling.
>
>5. It is further found that this failure (4.) causes identical,
>mechanical failures to secondary structure (beams) that
>
>6. in turn causes damages to adjacent primary structural columns that
>fail that
>
>7. in turn causes further failures to secondary structure (beams) that
>

>8. in turn causes damages to adjacent primary structural columns that
>fail, etc.
>
>
>
>The critical failure or failures and its cause (buckling of column no.
>79 - failure no. 4 - and unknown effects of the beam(s)) are thus those
>no. 5 above, as then the global collapse starts.
>Would that or those failures have been avoided (by clever design?) the
>global collapse would not have taken place.
>
>
>
>Evidently the failures continue, after the critical one has been
>reached, until total destruction, which of course is of less
>importance. But it is very good, that you do the analysis to the end;
>then also details of elements/parts getting completely detached from
>the structure can be identified (and later be compared with what was
>found in the rubble) in the report and how these loose parts are
>assumed to load, slip off or jam the structure after being detached.
>
>
>
>Evidently a global collapse is only possible if all primary parts of
>the structure are affected but we are interested in all local failures
>leading to the first critical failure that causes/initiates the
>collapse, e.g. no. 5 in the example above. The draft report is
>incomplete in this respect and should be expanded.
>
>
>
>I am personally quite surprised that the small local failures down
>below around a few columns are not arrested, when running out energy to
>produce further failures up top. Just because one or two column fails
>due to local failures, should not cause other, complete intact columns
>to fail far away.
>
>
>
>Actually, if the LS-DYNA software can produce what is suggested, it
>should be able to simulate all the structural conditions from (A) the
>completely intact, prior fire, cold condition,
>(B) all the part damaged conditions due local failures with still
>intact structure left including (C) the critical failure condition,
>when further destruction starts by gravity alone, and not least, (D)
>the end condition, when all structural parts or sub-assemblies are
>disconnected in the rubble at equilibrium on the ground.
>
>
>
>There are (D) huge blocks of structure in the rubble with broken
>primary parts (columns). The LS-DYNA software apparently can simulate
>how these big blocks bounded by failed elements came about, e.g. how
>the primary columns were sheared off away from bolted and welded
>connections, and ended up as seen on many photos. It is also a good
>test to verify the reliability of the LS-DYNA software, details of
>which are completely unknown to me. (Only reference to LS-DYNA is a
>user's manual of little value).

>
>
>
>If the LS-DYNA software is as good as suggested, it can be used in
>analysing structural damages in ship collisions and thus improve safety
>at sea (my principal interest).
>
>
>
>Summary of Submittal of Comments
>
>
>
>By using two complete (47 floors) models (ANSYS and LS-DYNA) to
>simulate the failures' path(s) leading to the critical failure
>initiating collapse, the reliability of the final result will improve.
>
>All failures in the path(s) should be described, particularly when
>secondary and primary structural elements start to fail and the status
>(stress or FoS levels) of the structure after each failure.
>
>The critical failure, e.g. the failure of a secondary structural
>element - a beam, that initiates the global collapse, must be described
>in detail and how it can affect undamaged remote structure, i.e. other
>primary columns, by e.g.
>load transfers as calculated by the software.
>
>As load transfers are only possible via secondary structure and
>connections, you wonder why not only those secondary parts fail,
>leaving the intact primary structure unloaded and unaffected (as they
>are also connected/supported by other beams that do not fail), i.e. the
>report must clearly explain why WTC7 collapsed like a house of cards
>that has never happened before.
>
>
>
>End
>
>

Submittal of Comments - NIST WTC7 report

Name: Anders Björkman, 6 rue Victor Hugo, F 06240 France
Affiliation: President, Heiwa Co, European Agency for Safety at Sea (address as above)
Contact: +336 61725424, **anders.bjorkman@wanadoo.fr**
Reference number: 2008/9/001
Date: 9/3/2008

Report Number: NIST NCSTAR 1-9 Volume 2
Page Number: 455-536
Paragraph/Sentence: **Chapter 11 - 11.2 ANSYS Model, 11.3 Analysis results**

Comment No. 1: In structural *damage* analysis - as opposite to structural *design* analysis - it is not load paths of the intact structure that is of interest, but the *path* of failures from the first small local failure due to a known cause (e.g. fire/heat/thermal expansion) to the end of destruction including *all* structural failures in between as a consequence of the first, small failure. Such a *damage* analysis shall identify the *critical* failure in the path, i.e. could that *critical* failure be avoided; *the destruction would have been arrested there*. Most local failures in steel structures luckily do not progress to create a critical failure that causes the complete structure to globally collapse. The destruction is generally arrested long before that.

The NIST WTC7 draft report unfortunately fails to do this proper structural *damage* analysis:

It is not clear in what order the various local structural failures take place in the ANSYS model, what elements/nodes are affected, details of failure, cause of failure and consequence of failure (serious or can it be ignored?) and how the boundary conditions (loads on columns at floor 16) are affected.

Reason for Comment: The ANSYS model, only 16 floors high in lieu of 47, consists of primary (vertical steel columns connected to ground), secondary (horizontal and sloping steel beams connected to primary parts) and tertiary parts (e.g. floor elements and walls connected to secondary parts; beams) and associated connections, and it is of vital importance to know the order or path of failures. We know that the structure at ambient temperature is very low stressed and thus looks very safe. Purpose of the exercise is to find the critical, proximate failure that caused the collapse.

Fire/heat/thermal expansion may affect a tertiary member that heats up quicker than adjacent secondary members and the local connections may fail and the tertiary part is out of action but it hardly affects the effectiveness of the secondary parts, which of course is verified when the FEA analysis is re-done after each failure. The secondary parts and their connections (bolted or welded) to primary parts are much stronger than those of tertiary parts and will deflect and deform with the primary parts and it is highly unlikely that thermal expansion will produce forces that break the much stronger connections between secondary and primary parts. It is noted that a critical failure mode may be buckling of one primary structure column losing supports by secondary structure floor beams.

Suggestions for Revision: Chapter 11.2 to be expanded with a list of all local failures in order of occurrence with details and seriousness as outlined above in Comment No. 1. After each failure the condition of the model is evidently re-analysed by FEA and the results of each element (primary, secondary and tertiary) summarized in Chapter 11.2. Doing that we will know when the situation becomes really serious, e.g. when/if a primary part starts to get affected. Evidently a global collapse is only possible if primary structural parts are affected and we are interested in all local failures leading to that critical failure; the proximate cause of collapse. The draft report Chapter 11 is incomplete in this respect.
Example how to improve the report:
1. ***Tertiary structural elements** connected to a floor beam fail due heat/thermal expansion.* These failures/causes are easy to list.
2. ***Secondary structural elements** (beams with or w/o floor elements) connected to a column fail.* These failures and their causes should also be easy to list, but here the explanations must be more complete. If, e.g. a beam connection to the column becomes disconnected, we must know exactly how and why (because you do not expect that to happen).
3. ***Primary structural elements** (e.g. column 79) fail.* If cause of failure is buckling due to loss of supports of secondary floor beams (and not thermal expansion), say so, but explain how many secondary structural beams must fail before the critical failure of the primary column becomes imminent. This failure to a column evidently

affects the boundary conditions, so you have to move on the next model to find out what really happens outside the model.
Unfortunately you do not know if this failure of a column in the ANSYS model is the *critical* one, as you do not know what happens above floor 16. Evidently a failed column cannot carry any load, so either the load carried drops off or is transmitted to other elements, but in either case the boundary conditions changes; the loads applied at floor 16 change!
It would be very easy to extend the ANSYS model to 47 floors to solve that uncertainty. Then you can see how each failure below floor 16 affects the load distribution above floor 16. **Thus it is suggested that the ANSYS model is also extended to floor 47 in your final analysis/report.**

Report Number: NIST NCSTAR 1-9 Volume 2
Page Number: 537-600
Paragraph/Sentence: **Chapter 12**

Comment No. 2: The LS-DYNA 47 floors model is very big with >3 million elements and >3.5 million nodes and the data of a partly damaged ANSYS model incl. boundary conditions is copy/pasted into it to represent the starting (stable?) condition with local damages below floor 16. As shown in Comment No. 1 the details of the damaged ANSYS model are not clear and it is not certain, if it represents a realistic starting condition. Another question is if you can copy/paste data of a locally damaged structure into an undamaged one? What about the boundary conditions at floor 16? Another question is the reliability of the LS-DYNA software. Has it been tested properly? It does not seem to be commercially available.

Reason for Comment: The LS-DYNA, like the ANSYS model, consists of primary (vertical columns connected to ground), secondary (horizontal and sloping beams connected to primary parts) and tertiary parts (e.g. floor and wall elements connected to secondary parts; beams) and associated connections, and it is again of vital importance to know the order or path of failures. We know that the structure at ambient temperature is very low stressed and thus looks very safe.

Heat/thermal expansion may at this time have affected tertiary parts below floor 16, the local connections of which may have failed and the tertiary part is out of action and it has apparently affected the effectiveness of the secondary parts, but the situation is not clear (as Chapter 11 is incomplete). The secondary parts and their connections to primary parts are much stronger than tertiary parts and will deform and deflect with the primary parts and it is highly unlikely that thermal expansion will produce forces that break the connections between secondary and primary parts. However, it is assumed here that some secondary and primary parts below floor 16 have actually failed (causes to be established) and shifted a column (No 79?) out of initial locations affecting the boundary conditions at floor 16, but that the structure below floor 16 is still stable.

It is of vital interest to know how these local failures below floor 16 immediately affect the virtually undamaged structure above, when (A) the analysis starts (how serious are the failures below?) and (B) every further failure that follows below and above floor 16 and finally, (C) at the end, when all parts are rubble.

It is evidently possible that when a primary column fails below floor 16, the load on it is transmitted to adjacent columns via intact structure *above* floor 16, i.e. the boundary conditions must be modified in the ANSYS model analysis. Was it done?

It is not clear how and why the software LS-DYNA can keep track of parts that are completely disconnected from the structure due to multiple failures.

Suggestion for Revision: The method to copy/paste details of the ANSYS (Chapter 11) model at end of assumed failures below floor 16 produces uncertainties.

It would be better to start afresh with the LS-DYNA model as completely free of failures and then input all the local - serious (?) failures - one by one - as identified in the ANSYS model below floor 16 and listed in Chapter 11.3 and see what happens everywhere at every initial, local failure and then proceed with the further failures, one by one, away from the first local non-critical failures, until the critical failure and its cause are identified.

Chapter 12 thus to be expanded with a list of all further local failures above and below floor 16 in order of occurrence with details and seriousness as outlined above in Comment No. 1. After each failure the condition of the model is evidently re-analysed by FEA and the results of each element (primary, secondary and tertiary) summarized in Chapter 12.4.

Doing that we will know when the situation becomes really serious, e.g. when/if other primary parts (than column no. 79) start to get affected and why and what the real, proximate failure of total collapse is - the *critical* failure - and when it occurs in the failure path. Looking at the ANSYS model data only, it seems that column 79 could collapse completely due to a known cause (buckling), but that it would be the end of the local (serious) destruction. The other columns should not be affected!

But apparently the failure of column 79 causes further failures of other primary parts and it needs to be explained - the failure path is to be extended. So Chapter 12 must be expanded with details of further failures leading to the final, critical one - the proximate failure initiating the global collapse. Would that proximate failure have been avoided for any reason, the destruction would have stopped then and there.
Example:
4. It is found that ***primary structural element column no. 79 fails*** due to buckling.
5. It is further found that this failure (4.) causes identical, mechanical failures to **secondary structure** (beams) that
6. in turn causes damages to **adjacent primary structural columns** that fail that
7. in turn causes further failures to secondary structure (beams) that
8. in turn causes damages to **adjacent primary structural columns** that fail, etc.

The *critical* failure or failures and its cause (buckling of column no. 79 - failure no. 4 - and unknown effects of the beam(s)) are thus those no. **5** above, as then the global collapse starts. Would that or those failures have been avoided (by clever design?) the global collapse would not have taken place.

Evidently the failures continue, after the *critical* one has been reached, until total destruction, which of course is of less importance. But it is very good, that you do the analysis to the end; then also details of elements/parts getting completely detached from the structure can be identified (and later be compared with what was found in the rubble) in the report and how these loose parts are assumed to load, slip off or jam the structure after being detached.

Evidently a global collapse is only possible if *all* primary parts of the structure are affected but we are interested in all local failures leading to the first *critical* failure that causes/initiates the collapse, e.g. no. 5 in the example above. The draft report is incomplete in this respect and should be expanded.

I am personally quite surprised that the small local failures down below around a few columns are not arrested, when running out energy to produce further failures up top. Just because one or two column fails due to local failures, should not cause other, complete intact columns to fail far away.

Actually, if the LS-DYNA software can produce what is suggested, it should be able to simulate all the structural conditions from (A) the completely intact, prior fire, cold condition, (B) all the part damaged conditions due local failures with still intact structure left including (C) the *critical* failure condition, when further destruction starts by gravity alone, and not least, (D) the end condition, when all structural parts or sub-assemblies are disconnected in the rubble at equilibrium on the ground.

There are (D) huge blocks of structure in the rubble with broken primary parts (columns). The LS-DYNA software apparently can simulate how these big blocks bounded by failed elements came about, e.g. how the primary columns were sheared off away from bolted and welded connections, and ended up as seen on many photos. It is also a good test to verify the reliability of the LS-DYNA software, details of which are completely unknown to me. (Only reference to LS-DYNA is a user's manual of little value).

If the LS-DYNA software is as good as suggested, it can be used in analysing structural damages in ship collisions and thus improve safety at sea (my principal interest).

Summary of Submittal of Comments

By using two complete (47 floors) models (ANSYS and LS-DYNA) to simulate the *failures' path(s)* leading to the critical failure initiating collapse, the reliability of the final result will improve.
All failures in the path(s) should be described, particularly when secondary and primary structural elements start to fail and the status (stress or FoS levels) of the structure after each failure.

The *critical* failure, e.g. the failure of a secondary structural element - a beam, that initiates the global collapse, must be described in detail and how it can affect undamaged remote structure, i.e. other primary columns, by e.g. load transfers as calculated by the software.
As load transfers are only possible via secondary structure and connections, you wonder why not only those secondary parts fail, leaving the intact primary structure unloaded and unaffected (as they are also connected/supported by other beams that do not fail), i.e. the report must clearly explain why WTC7 collapsed like a house of cards that has never happened before.

End